



# ABRS Hardware Manual

Revision: 1.08.00



## Global Technical Support

Go to [www.aerotech.com/global-technical-support](http://www.aerotech.com/global-technical-support) for information and support about your Aerotech products. The website supplies software, product manuals, Help files, training schedules, and PC-to-PC remote technical support. If necessary, you can complete Product Return (RMA) forms and get information about repairs and spare or replacement parts. To get help immediately, contact a service office or your sales representative. Include your customer order number in your email or have it available before you call.

United States (World Headquarters)	
Email: Support@ aerotech.com Phone: +1-412-967-6440 Fax: +1-412-967-6870	101 Zeta Drive Pittsburgh, PA 15238-2811 www.aerotech.com
United Kingdom	China
Email: Support@ aerotech.com Phone: +44 (0)1256 855055 Fax: +44 (0)1256 855649	Email: Support@ aerotech.com Phone: +86 (21) 5508 6731
Germany	Taiwan
Email: Support@ aerotech.com Phone: +49 (0)911 967 9370 Fax: +49 (0)911 967 93720	Email: Support@ aerotech.com Phone: +886 (0)2 8751 6690
France	
Email: Support@ aerotech.com Phone: +33 2 37 21 87 65	

This manual contains proprietary information and may not be reproduced, disclosed, or used in whole or in part without the express written permission of Aerotech, Inc. Product names mentioned herein are used for identification purposes only and may be trademarks of their respective companies.

Copyright © 2006-2020, Aerotech, Inc., All rights reserved.

## Aerotech Worldwide

United States ■ France ■ Germany ■ United Kingdom  
China ■ Taiwan



## Table of Contents

<b>ABRS Hardware Manual</b>	<b>1</b>
Table of Contents	3
List of Figures	4
List of Tables	5
Safety Procedures and Warnings	6
EU Declaration of Incorporation	7
<b>Chapter 1: Overview</b>	<b>9</b>
1.1. Environmental Specifications	10
1.2. Accuracy and Temperature Effects	10
1.3. Basic Specifications	11
1.4. Air Requirements	12
1.5. Vacuum Operation	12
<b>Chapter 2: Installation</b>	<b>13</b>
2.1. Unpacking and Handling the Stage	13
2.2. Dimensions	14
2.3. Securing the Stage to the Mounting Surface	18
2.4. Attaching the Payload to the Stage	20
<b>Chapter 3: Electrical Installation</b>	<b>21</b>
3.1. Motor and Feedback Connectors	22
3.2. Motor and Feedback Wiring	26
3.3. Motor and Feedback Specifications	28
3.4. Limits, Marker, and Machine Direction	33
3.5. Motor and Feedback Phasing	34
<b>Chapter 4: Maintenance</b>	<b>37</b>
4.1. Service and Inspection Schedule	37
4.2. Cleaning and Lubrication	38
4.3. Troubleshooting	39
<b>Appendix A: Warranty and Field Service</b>	<b>41</b>
<b>Appendix B: Revision History</b>	<b>43</b>
<b>Index</b>	<b>45</b>

## List of Figures

Figure 1-1:	ABRS Series Rotary Air-Bearing Stage .....	9
Figure 2-1:	ABRS150MP Dimensions .....	14
Figure 2-2:	ABRS200MP Dimensions .....	15
Figure 2-3:	ABRS250MP Dimensions .....	16
Figure 2-4:	ABRS300MP Dimensions .....	17
Figure 2-5:	Top View of an ABRS250MP Stage Showing Mounting Holes .....	19
Figure 2-6:	Side View of an ABRS250MP Stage Showing Tapped Fixturing Holes .....	19
Figure 3-1:	Motor and Feedback Wiring (single connector, ABRS150MP) .....	26
Figure 3-2:	Motor and Feedback Wiring (two connectors, ABRS200MP, ABRS250MP, ABRS300MP) .....	27
Figure 3-3:	Machine Direction .....	33
Figure 3-4:	Hall Phasing .....	34
Figure 3-5:	Analog Encoder Phasing Reference Diagram (-E1 Encoder Option) .....	35
Figure 3-6:	Digital Encoder Phasing Reference Diagram (-E2 Encoder Option) .....	35

## List of Tables

Table 1-1:	Model Options .....	9
Table 1-2:	Environmental Specifications .....	10
Table 1-3:	ABRS Series Specifications .....	11
Table 2-1:	Stage to Mounting Surface Hardware .....	18
Table 2-2:	ABRS Series Load Capability .....	20
Table 3-1:	25-Pin Motor and Feedback Connector Pinout .....	23
Table 3-2:	Mating Connector Part Numbers for the 25-Pin Motor and Feedback Connector .....	23
Table 3-3:	4-Pin Motor Connector Pinout .....	24
Table 3-4:	Mating Connector Part Numbers for the 4-Pin Motor Connector .....	24
Table 3-5:	25-Pin Feedback Connector Pinout .....	25
Table 3-6:	Mating Connector Part Numbers for the 25-Pin Feedback Connector .....	25
Table 3-7:	Feedback Specifications .....	28
Table 3-8:	Encoder Resolution Specifications .....	28
Table 3-9:	Maximum Speed (rpm) Per Encoder Option .....	28
Table 3-10:	ABRS150MP Motor Specifications (S-50-39-A) .....	29
Table 3-11:	ABRS200MP Motor Specifications (S-76-35-A) .....	30
Table 3-12:	ABRS250MP Motor Specifications (S-130-39-A) .....	31
Table 3-13:	ABRS300MP Motor Specifications (S-180-44-A) .....	32

## Safety Procedures and Warnings



This manual tells you how to carefully and correctly use and operate the ABRS.

- Read all parts of this manual before you install or operate the ABRS or before you do maintenance to your system.
- To prevent injury to you and damage to the equipment, obey the precautions in this manual.



If you do not understand the information in this manual, contact Aerotech Global Technical Support.

**NOTE:** Aerotech continually improves its product offerings; listed options may be superseded at any time. All drawings and illustrations are for reference only and were complete and accurate as of this manual's release. Refer to [www.aerotech.com](http://www.aerotech.com) for the most up-to-date information.



**DANGER:** This product contains potentially lethal voltages. To reduce the possibility of electrical shock, bodily injury, or death the following precautions must be followed.

1. Access to the ABRS and component parts must be restricted while connected to a power source.
2. Do not connect or disconnect any electrical components or connecting cables while connected to a power source.
3. Disconnect electrical power before servicing equipment.
4. All components must be properly grounded in accordance with local electrical safety requirements.
5. Operator safeguarding requirements must be addressed during final integration of the product.



**WARNING:** To minimize the possibility of electrical shock, bodily injury or death the following precautions must be followed.

1. Moving parts can cause crushing or shearing injuries. Access to all stage and motor parts must be restricted while connected to a power source.
2. Cables can pose a tripping hazard. Securely mount and position all system cables to avoid potential hazards.
3. Do not expose this product to environments or conditions outside of the listed specifications. Exceeding environmental or operating specifications can cause damage to the equipment.
4. The ABRS stage must be mounted securely. Improper mounting can result in injury and damage to the equipment.
5. Use care when moving the ABRS stage. Lifting or transporting the ABRS stage improperly can result in injury or damage to the ABRS.
6. This product is intended for light industrial manufacturing or laboratory use. Use of this product for unintended applications can result in injury and damage to the equipment.
7. If the product is used in a manner not specified by the manufacturer, the protection provided by the product can be impaired and result in damage, shock, injury, or death.
8. Operators must be trained before operating this equipment.
9. All service and maintenance must be performed by qualified personnel.

## EU Declaration of Incorporation

**Manufacturer:** Aerotech, Inc.  
101 Zeta Drive  
Pittsburgh, PA 15238-2811  
USA

***herewith declares that the product:***

ABRS Air-Bearing Direct Drive Rotary Stage

*is intended to be incorporated into machinery to constitute machinery covered by the Directive 2006/42/EC as amended;*

*and that the following harmonized European standards have been applied:*

EN ISO 12100:2010

Safety of machinery - Basic concepts, general principles for design

EN 60204-1:2010

Safety of machinery - Electrical equipment of machines - Part 1: General requirements

*and further more declares that*

it is not allowed to put the equipment into service until the machinery into which it is to be incorporated or of which it is to be a component has been found and declared to be in conformity with the provisions of the Directive 2006/42/EC and with national implementing legislation, for example, as a whole, including the equipment referred to in this Declaration.

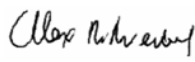
*This is to certify that the aforementioned product is in accordance with the applicable requirements of the following Directive(s):*

EU 2015/863

RoHS 3 Directive

**Authorized Representative:** Simon Smith, European Director  
**Address:** Aerotech Ltd  
The Old Brick Kiln, Ramsdell, Tadley  
Hampshire RG26 5PR  
UK

**Name**

 / Alex Weibel

**Position**

Engineer Verifying Compliance

**Location**

Pittsburgh, PA

**Date**

7/17/2020



*This page intentionally left blank.*

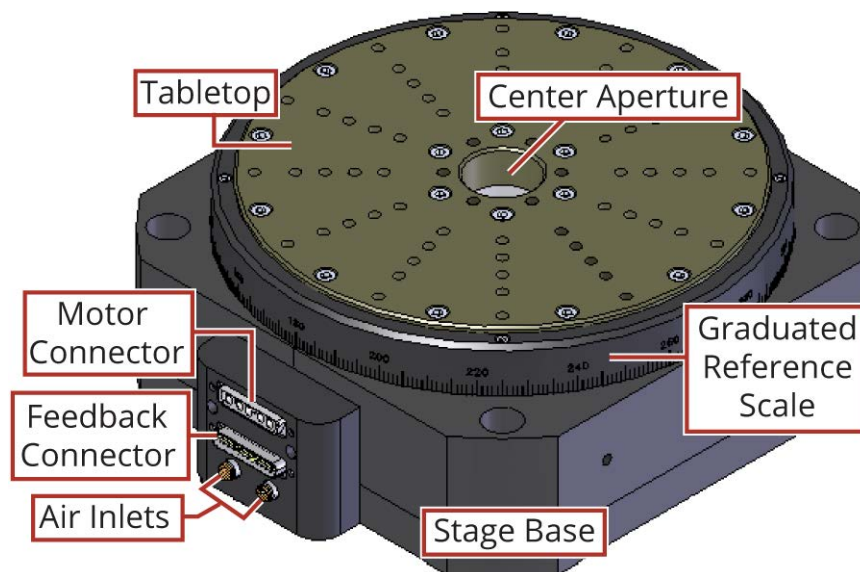


## Chapter 1: Overview

**NOTE:** Aerotech continually improves its product offerings; listed options may be superseded at any time. All drawings and illustrations are for reference only and were complete and accurate as of this manual's release. Refer to [www.aerotech.com](http://www.aerotech.com) for the most up-to-date information.

**Table 1-1: Model Options**

ABRS Series Air-Bearing Direct-Drive Rotary Stage	
ABRS150MP	150 mm wide air-bearing rotary stage with 0.82 N·m peak torque output
ABRS200MP	200 mm wide air-bearing rotary stage with 2.12 N·m peak torque output
ABRS250MP	250 mm wide air-bearing rotary stage with 9.42 N·m peak torque output
ABRS300MP	300 mm wide air-bearing rotary stage with 23.98 N·m peak torque output
Feedback (Required)	
-E1	Incremental encoder, 1 Vpp
-E2	Incremental encoder, Digital RS422 (x50 interpolation)
Accessories (To be Ordered as a Separate Line Item)	
-ABF	Air bearing filtration kit



**Figure 1-1: ABRS Series Rotary Air-Bearing Stage**

## 1.1. Environmental Specifications

**Table 1-2: Environmental Specifications**

<b>Ambient Temperature</b>	Operating: 10° to 35° C (50° to 95° F) The optimal operating temperature is 20° C $\pm$ 2° C (68° F $\pm$ 4° F). If at any time the operating temperature deviates from 20° C, degradation in performance could occur.
	Storage: 0° to 40° C (32° to 104° F) in original shipping packaging
<b>Humidity</b>	Operating: 20% to 60% RH
	Storage: 10% to 70% RH, non-condensing in original packaging
<b>Altitude</b>	Operating: 0 m to 2,000 m (0 ft to 6,562 ft) above sea level Contact Aerotech if your specific application involves use above 2,000 m or below sea level.
<b>Vibration</b>	Use the system in a low vibration environment. Excessive floor or acoustical vibration can affect system performance. Contact Aerotech for information regarding your specific application.
<b>Protection Rating</b>	The ABRS stages are not suited for dusty or wet environments. This equates to an ingress protection rating of IP00.
<b>Use</b>	Indoor use only



**WARNING:** Do not expose this product to environments or conditions outside of the listed specifications. Exceeding environmental or operating specifications can cause damage to the equipment.

## 1.2. Accuracy and Temperature Effects

Aerotech products are designed for and built in a 20°C (68°F) environment. Extreme temperature changes could cause a decrease in performance or permanent damage to the ABRS. At a minimum, the environmental temperature must be controlled to within 0.25°C per 24 hours to ensure the ABRS specifications are repeatable over an extended period of time. The severity of temperature effects on all specifications depends on many different environmental conditions, including how the ABRS is mounted. Contact the factory for more details.

## 1.3. Basic Specifications

**NOTE:** Aerotech continually improves its product offerings; listed options may be superseded at any time. All drawings and illustrations are for reference only and were complete and accurate as of this manual's release. Refer to [www.aerotech.com](http://www.aerotech.com) for the most up-to-date information.

Resolution is dependent upon the encoder resolution and the controller interpolation.

**Table 1-3: ABRS Series Specifications**

ABRS Series		ABRS150MP	ABRS200MP	ABRS250MP	ABRS300MP
Width		150 mm	200 mm	250 mm	300 mm
Tabletop Diameter		128.1 mm	178.1 mm	228.1 mm	278.1 mm
Height		80 mm	90 mm	100 mm	110 mm
Aperture		8 mm	20 mm	35 mm	75 mm
Travel		±360° Continuous			
Bus voltage		80 VDC	340 VDC		
Fundamental Encoder Resolution		3600 lines/rev	8192 lines/rev	11,840 lines/rev	18,000 lines/rev
Max Speed <sup>(1)</sup>		300 rpm	300 rpm	500 rpm	500 rpm
Accuracy <sup>(2)</sup>		±3 arc sec	±2 arc sec	±2 arc sec	±2 arc sec
Bidirectional Repeatability		<2 arc sec	<1 arc sec	<1 arc sec	<1 arc sec
Max Load <sup>(3)</sup>	Axial	8 kg	31 kg	66 kg	97 kg
	Radial	4 kg	15 kg	36 kg	51 kg
	Tilt	3 N·m	10 N·m	28 N·m	45 N·m
Axial Error	Synchronous	<175 nm	<100 nm	<100 nm	<100 nm
	Asynchronous	<20 nm			
Radial Error	Synchronous	<450 nm	<250 nm	<250 nm	<250 nm
	Asynchronous	<20 nm			
Tilt Error <sup>(4)</sup>	Synchronous	<9.7 µrad (<2.0 arc sec)	<3.4 µrad (<0.7 arc sec)	<2.4 µrad (<0.5 arc sec)	<2.4 µrad (<0.5 arc sec)
	Asynchronous	<0.4 µrad (<0.08 arc sec)	<0.3 µrad (<0.06 arc sec)	<0.2 µrad (<0.04 arc sec)	<0.2 µrad (<0.04 arc sec)
Operating Pressure <sup>(5)</sup>		80 psig (5.5 bar) + 0 psig (0.0 bar)/-10 psig (0.7 bar)			
Air Consumption <sup>(6)</sup>		<56.6 SLPM (<2 SCFM)			
Inertia (unloaded)		3,850 kg·mm <sup>2</sup>	13,800 kg·mm <sup>2</sup>	39,100 kg·mm <sup>2</sup>	102,000 kg·mm <sup>2</sup>
Total Mass		4.8 kg	9.1 kg	15.6 kg	24.5 kg
Material		Aluminum			
Finish		Hard Coating (62 Rockwell Hardness)			
1. Maximum speed based on stage capability. Maximum application velocity may be limited by system data rate and system resolution.					
2. Certified with each stage. Requires the use of an Aerotech controller.					
3. Maximum loads are mutually exclusive.					
4. All error motion specifications are measured at 60 rpm.					
5. To protect air bearing against under-pressure, an in-line pressure switch tied to the motion controller/amplifier E-Stop is recommended.					
6. Air supply must be clean, dry to 0° F dew point and filtered to 0.25 µm or better. Recommend nitrogen at 99.9% purity.					

## 1.4. Air Requirements



**WARNING:** Wear eye protection when you are close to compressed air components.



**WARNING:** Do not attempt to rotate the stage table until the air supply has been installed. If separate thrust and journal ports are present, air must be supplied to both. Moving the stage table without air supplied can cause permanent damage to the stage.

Connect the air supply hose(s) to the air inlet fitting(s). The location of the air inlet(s) is shown in the dimensional drawings ([Section 2.2.](#)).

It is important to the operation of the ABRS that the air supply meets Aerotech specifications. For compressed air, the air must be filtered to 0.25 microns, dry to 0°F dew point, and oil free. For nitrogen, the nitrogen must be 99.99% pure and filtered to 0.25 microns. Filtration is required to prevent particles from clogging the air bearing orifices and other parts.

Air pressure must be in the range of 551 kPa  $\pm$  34 kPa (80 psi  $\pm$  5 psi) with an airflow rate of 56 SLPM (standard liters per minute) at 551 kPa for a single axis. Aerotech recommends that you connect the air supply with a polyurethane air hose.

Aerotech also recommends that you install a pressure switch (Aerotech P/N: MCA03094) tied to the motion controller's emergency stop (ESTOP) that will remove power to the air bearing if pressure drops below 40 psi (a drop in pressure could result in contact between bearing surfaces which could cause damage to the surfaces). Aerotech's ABF accessory kit incorporates air filtration plus a pressure monitoring switch.

Some stage models include a separate port for the thrust and journal air bearings. In some applications, you could want to "lock-down" the stage by removing air pressure to the thrust bearing while air pressure is maintained to the journal bearing. Power must be removed from the stage while it is "locked-down" to avoid damage to the thrust bearing surfaces. It is highly recommended to consult the factory for detailed assistance if this "lock-down" feature is to be used.

## 1.5. Vacuum Operation

The ABRS is an air-bearing stage and is not compatible with operation in a vacuum environment. Contact Aerotech for alternate solutions.

## Chapter 2: Installation



**WARNING:** ABRS installation must be in accordance to instructions provided by this manual and any accompanying documentation. Failure to follow these instructions could result in injury or damage to the equipment.

### 2.1. Unpacking and Handling the Stage



**DANGER/HEAVY:** Do not attempt to manually lift a stage that is too heavy (in excess of 18 kg). Refer to [Section 1.3](#) for stage mass specifications.

- Do not attempt to manually lift heavy loads single handed.
- Use a fork lift or cart to transport the stage.



**WARNING:** It is the customer's responsibility to safely and carefully lift the stage.

- Make sure that all moving parts are secure before moving the ABRS. Unsecured moving parts may shift and cause bodily injury.
- Improper handling could adversely affect the performance of the ABRS. Use care when moving the ABRS.
- Lift only by the base. Do not use the tabletop or cables as lifting points.

**NOTE:** If any damage has occurred during shipping, report it immediately.

Carefully remove the ABRS stage from its protective shipping container.

- Lift only from the base.
- Do not use any of the cables as lifting points.
- Do not use the tabletop as a lifting point.



**WARNING:** Do not attempt to rotate the stage table until the air supply, detailed in [Section 1.4](#), has been installed. If separate thrust and journal ports are present, air must be supplied to both. Moving the stage table without air supplied can cause permanent damage to the stage.

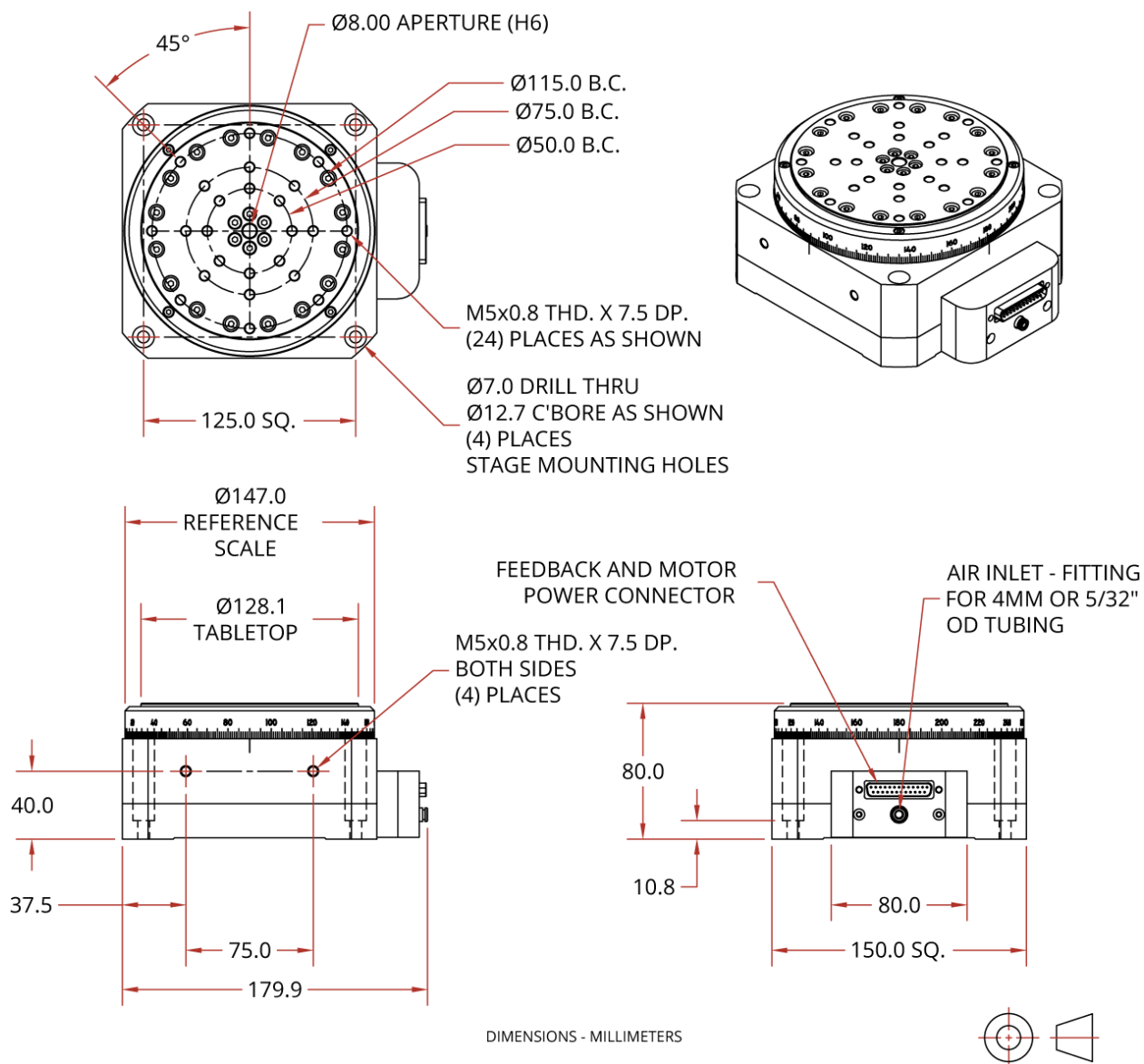
Gently set the ABRS stage on a smooth, flat, and clean surface.

Allow the stage to stabilize at room temperature for at least 12 hours before you attempt to operate it. A stabilized stage will ensure that all of the alignments, preloads, and tolerances are the same as they were when tested at Aerotech. Use compressed nitrogen or clean, dry, oil-free air to remove any dust or debris that has collected during shipping.

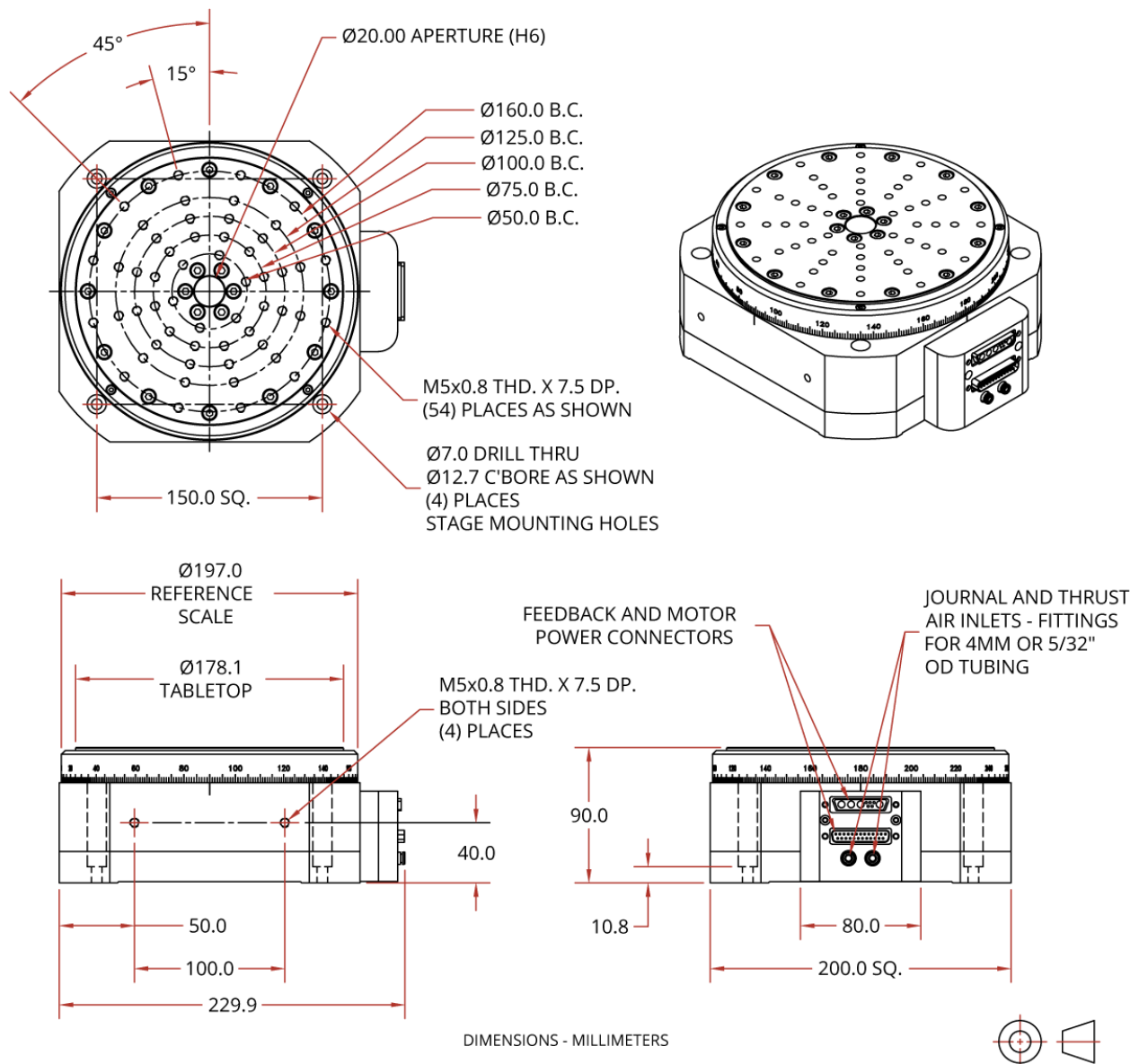
Each ABRS has a label listing the system part number and serial number. These numbers contain information necessary for maintaining or updating system hardware and software. Locate this label and record the information for later reference.

## 2.2. Dimensions

**NOTE:** Aerotech continually improves its product offerings; listed options may be superseded at any time. All drawings and illustrations are for reference only and were complete and accurate as of this manual's release. Refer to [www.aerotech.com](http://www.aerotech.com) for the most up-to-date information.



**Figure 2-1: ABRS150MP Dimensions**



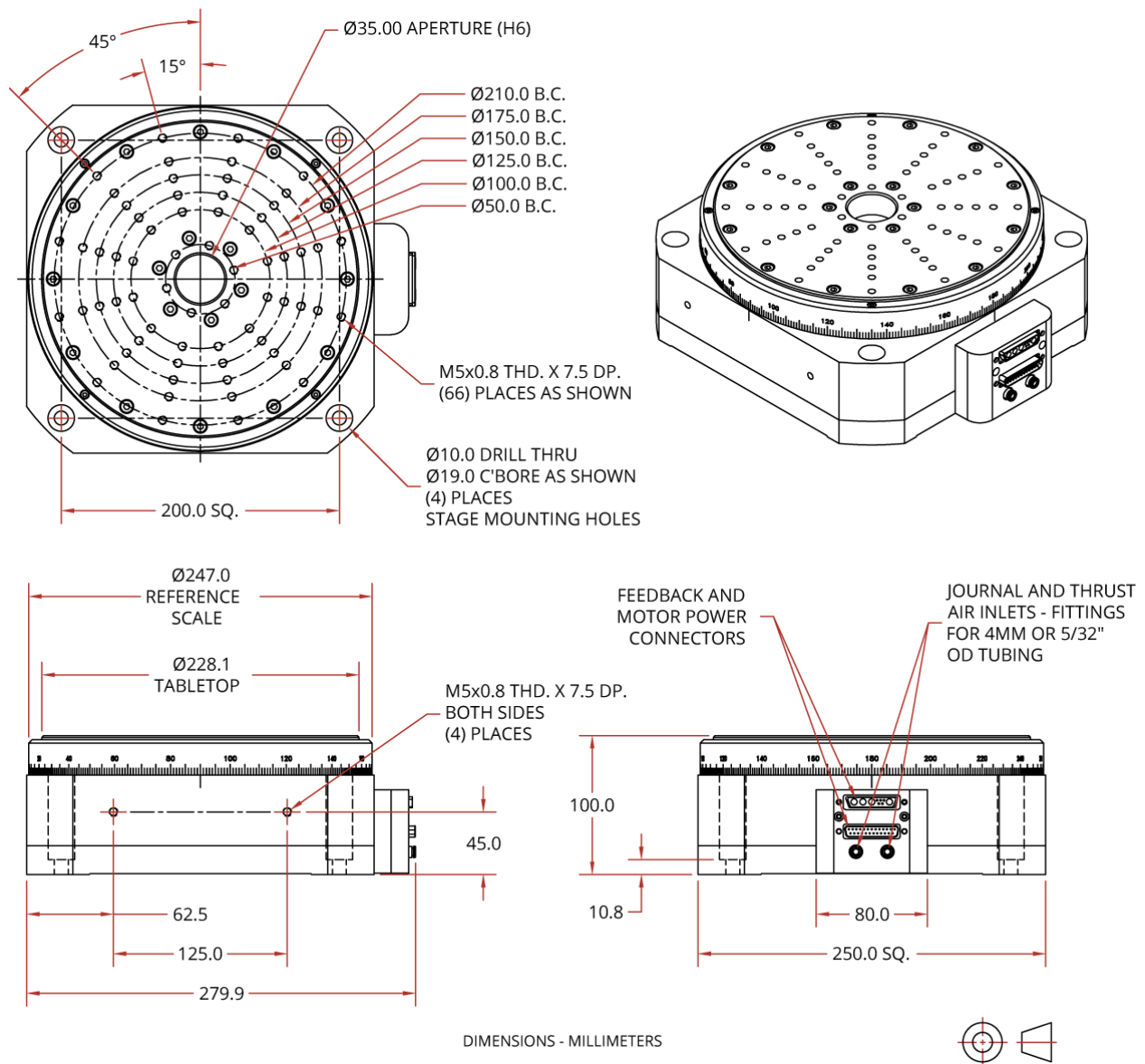


Figure 2-3: ABRS250MP Dimensions



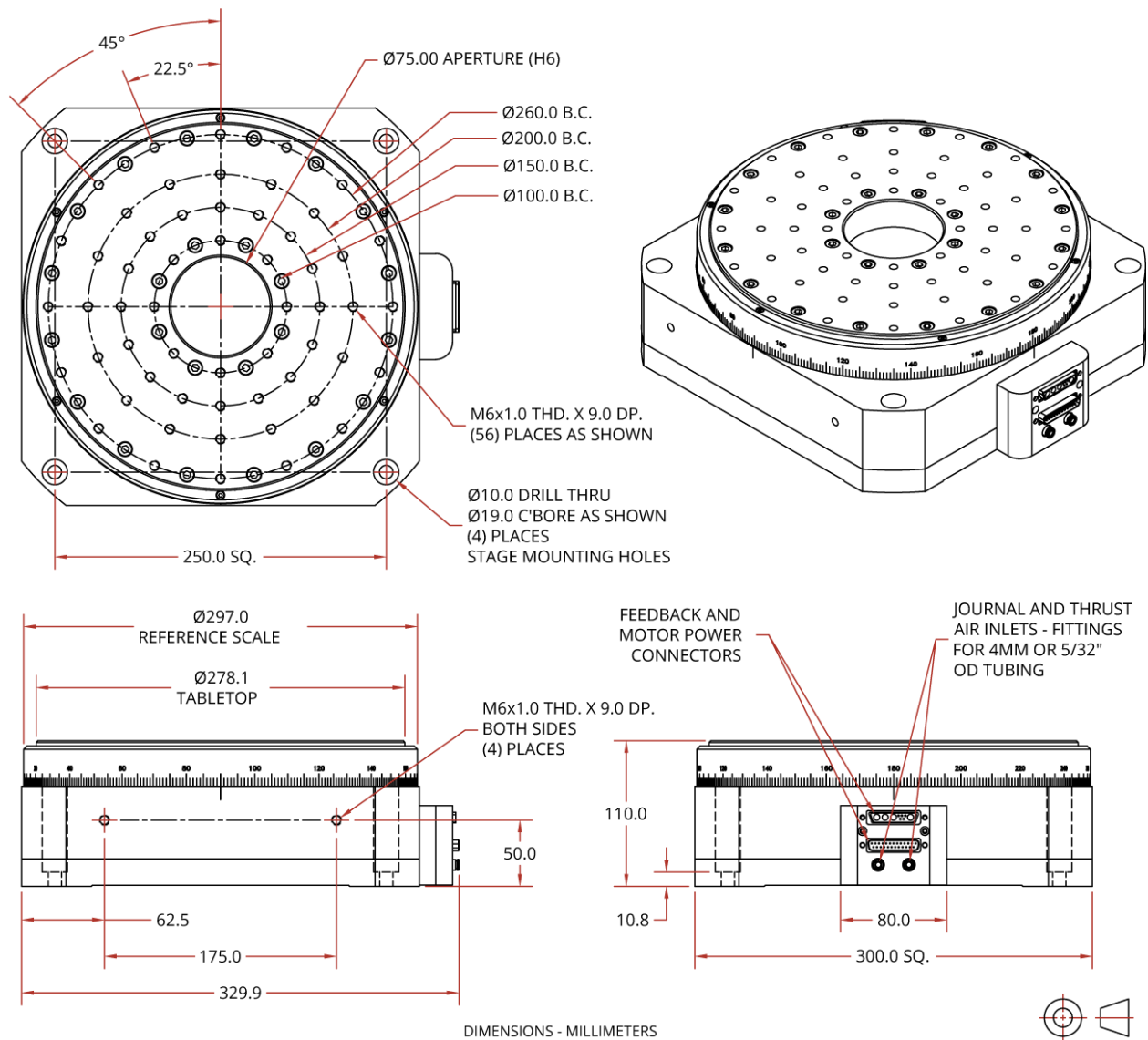


Figure 2-4: ABRS300MP Dimensions

## 2.3. Securing the Stage to the Mounting Surface



**WARNING :** Make sure that all moving parts are secure before moving the ABRS. Unsecured moving parts may shift and cause bodily injury.



**WARNING :** Do not attempt to manually move the ABRS if it is connected to a power source.



**WARNING :** The ABRS must be mounted securely. Improper mounting can result in injury and damage to the equipment.

The mounting surface must be flat and have adequate stiffness to achieve the maximum performance from the ABRS stage. When it is mounted to a non-flat surface, the stage can be distorted while the mounting screws are tightened. This distortion will decrease overall accuracy. Adjustments to the mounting surface must be done before the stage is secured.

Inspect the mounting surface for dirt or unwanted residue and clean if necessary. Use precision flatstones on the mounting surface to remove any burrs or high spots. Clean the mounting surface with a lint-free cloth and acetone or isopropyl alcohol and allow the cleaning solvent to completely dry. Gently place the stage on the mounting surface.

**NOTE :** To maintain accuracy, the mounting surface must be flat to within 2  $\mu\text{m}$  TIR.

**NOTE :** The stage base is precision machined and verified for flatness prior to stage assembly at the factory. If machining is required to achieve the desired flatness, it should be performed on the mounting surface rather than the stage base. Shimming should be avoided if possible. If shimming is required, it should be minimized to improve the rigidity of the system.

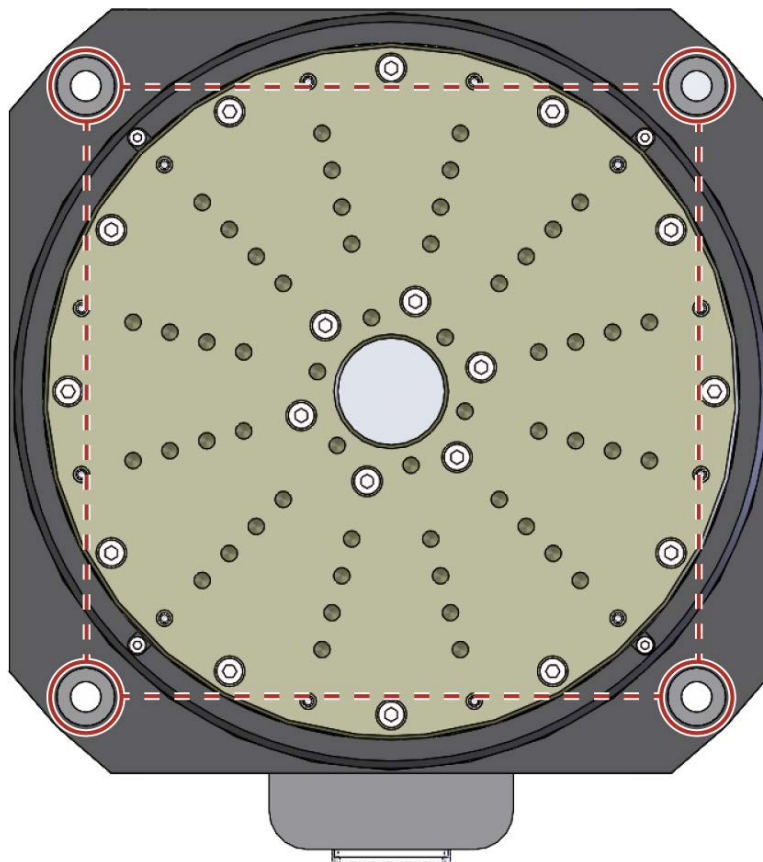
ABRS series stages have a fixed mounting pattern (as shown in [Figure 2-5](#)).

The ABRS should be mounted with the axis of rotation in the vertical direction using the counterbored mounting holes shown in [Figure 2-5](#). Mounting the stage with the axis of rotation in a horizontal orientation is not recommended because this orientation can have a negative effect on performance. Do not use the tapped fixturing holes shown in [Figure 2-6](#) to mount the stage in either axis of rotation orientation. Consult Aerotech for more information if your application requires a horizontal axis of rotation configuration.

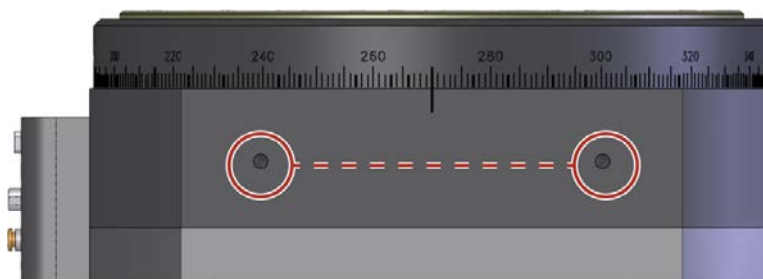
Tightening torque values for the mounting hardware are dependent on the properties of the surface to which the stage is being mounted. Values provided in [Table 2-1](#) are typical values and may not be accurate for your mounting surface. Refer to [Section 2.2](#) for specific model mounting locations and dimensions.

**Table 2-1: Stage to Mounting Surface Hardware**

Mounting Hardware		Typical Screw Torque
ABRS150, ABRS200	6 mm SHCS	7 N·m
ABRS250, ABRS300	8 mm SHCS	17 N·m



**Figure 2-5: Top View of an ABRS250MP Stage Showing Mounting Holes**



**Figure 2-6: Side View of an ABRS250MP Stage Showing Tapped Fixturing Holes**

## 2.4. Attaching the Payload to the Stage

Inspect the mounting surface for dirt or unwanted residue and clean if necessary. Clean the mounting surface with a lint-free cloth and acetone or isopropyl alcohol and allow the cleaning solvent to completely dry.

Aerotech recommends that customers use a representative payload during start-up to prevent accidental damage to the stage and the payload. Proceed with the electrical installation and test the motion control system in accordance with the system documentation. Document all results for future reference. For information on electrical installation refer to [Chapter 3](#) and the documentation delivered with the stage.

**NOTE:** If your ABRS was purchased with Aerotech controls, it might have been tuned with a representative payload based on the information provided at the time of order. If the ABRS is started up without a payload, the servo gains provided by Aerotech with the shipment may not be appropriate and servo instability can occur. Refer to the controller help file for tuning assistance.

The payload must be flat, rigid, and comparable to the stage in quality to maintain optimum performance. Additionally, the payload must be reasonably balanced in order to maintain stage accuracy. Consult Aerotech to determine if the payload may potentially result in any deterioration of stage performance.

Refer to [Section 2.2](#) for the location of the mounting holes on the stage tabletop to mount payloads. The payload mounting holes have reinforced threads to allow frequent removal and installation of mounting screws.

**NOTE:** For valid system performance, the mounting interface should be flat within 2  $\mu\text{m}$  TIR.



**WARNING:** Refer to the dimensions in [Section 2.2](#) for maximum allowable thread engagement. A screw extending through the stage table can affect travel and damage the stage.

The ABRS rotary stage loading specifications are shown in [Table 2-2](#).

**Table 2-2: ABRS Series Load Capability**

	ABRS150MP	ABRS200MP	ABRS250MP	ABRS300MP
Max Load - Axial*	8 kg	31 kg	66 kg	97 kg
Max Load - Radial*	4 kg	15 kg	36 kg	51 kg
Max Load - Tilt*	3 N·m	10 N·m	28 N·m	45 N·m
* Maximum loads are mutually exclusive.				

## Chapter 3: Electrical Installation



**WARNING:** Electrical installation must be performed by properly qualified personnel.

Electrical installation requirements will vary depending on product options. Installation instructions in this section are for ABRS stages equipped with standard Aerotech motors intended for use with an Aerotech motion control system. Contact Aerotech for further information regarding products that are otherwise configured.

Aerotech motion control systems are adjusted at the factory for optimum performance. When the ABRS is part of a complete Aerotech motion control system, setup usually involves connecting the ABRS to the appropriate drive chassis with the cables provided. Labels on the system components usually indicate the appropriate connections.

If system level integration was purchased, an electrical drawing showing system interconnects has been supplied with the system (separate from this documentation).

The electrical wiring from the motor and encoder are integrated at the factory. Refer to the sections that follow for standard motor wiring and connector pinouts.



**WARNING:** Operator access to the base and tabletop must be restricted while connected to a power source. Failure to do so could expose the operator to electrical shock or mechanical dangers.



**DANGER:** Remove power before connecting or disconnecting electrical components or cables. Failure to do so could cause electric shock or damage to the equipment.



**WARNING:** Applications that require access to the ABRS must be restricted to qualified and trained personnel. The system integrator or qualified installer is responsible for determining and meeting all safety and compliance requirements when they integrate the ABRS into a completed system.

### 3.1. Motor and Feedback Connectors

Stages equipped with standard motors and encoders come from the factory completely wired and assembled.

**NOTE:** Refer to the other documentation accompanying your Aerotech equipment. Call your Aerotech representative if there are any questions on system configuration.

**NOTE:** If using standard Aerotech motors and cables, motor and encoder connection adjustments are not required.

The protective ground connection of the ABRS provides motor frame ground protection only. Additional grounding and safety precautions are required for applications requiring access to the stage while it is energized. The System Integrator or qualified installer is responsible for determining and meeting all safety and compliance requirements necessary for the integration of this stage into the final application.



**DANGER:** Remove power before connecting or disconnecting electrical components or cables. Failure to do so could cause electric shock or damage to the equipment.




**WARNING:** The protective ground connection must be properly installed to minimize the possibility of electric shock.



**CAUTION:** The stage controller must provide over-current and over-speed protection. Failure to do so could cause electric shock or damage to the equipment..


**ABRS150MP:****Table 3-1: 25-Pin Motor and Feedback Connector Pinout**

Pin	Description	Connector
Case	Shield Connection	
1	Connector key (to prevent improper connection)	
2	Cosine-N	
3	Sine-N	
4	Marker-N	
5	Common ground	
6	Common ground	
7	Reserved	
8	Hall Effect sensor, phase A	
9	Hall Effect sensor, phase C	
10	Frame Ground	
11	Motor Phase A	
12	Motor Phase B	
13	Motor Phase C	
14	Cosine	
15	Sine	
16	Marker	
17	Encoder +5 V	
18	Reserved	
19	Reserved	
20	Thermistor	
21	Hall Effect sensor, phase B	
22	Frame Ground	
23	Motor Phase A	
24	Motor Phase B	
25	Motor Phase C	

**Table 3-2: Mating Connector Part Numbers for the 25-Pin Motor and Feedback Connector**

Mating Connector	Aerotech P/N	Third Party P/N
Backshell	ECK00656	Amphenol #17E-1726-2
Connector	ECK00300	FCI DB25S064TLF

**ABRS200MP, ABRS250MP, ABRS300MP:****Table 3-3: 4-Pin Motor Connector Pinout**

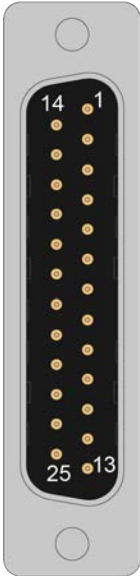
Pin	Description	Connector
Case	Shield Connection	
A1	Motor Phase A	
A2	Motor Phase B	
A3	Motor Phase C	
1	Reserved	
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
A4	Frame Ground (motor protective ground)	

**Table 3-4: Mating Connector Part Numbers for the 4-Pin Motor Connector**

Mating Connector	Aerotech P/N	Third Party P/N
Backshell	ECK00656	Amphenol #17E-1726-2
Sockets [QTY. 4]	ECK00659	ITT Cannon #DM53744-6
Connector	ECK00657	ITT Cannon #DBM9W4SA197



**Table 3-5: 25-Pin Feedback Connector Pinout**

Pin	Description	Connector
Case	Shield Connection	
1	Reserved	
2	Over-Temperature Thermistor sensor	
3	Encoder +5 V	
4	Reserved	
5	Hall Effect sensor, phase B	
6	Marker-N	
7	Marker	
8	Reserved	
9	Reserved	
10	Hall Effect sensor, phase A	
11	Hall Effect sensor, phase C	
12	Reserved	
13	Reserved	
14	Cosine	
15	Cosine-N	
16	Encoder +5 V	
17	Sine	
18	Sine-N	
19	Reserved	
20	Common	
21	Common	
22	Reserved	
23	Reserved	
24	Reserved	
25	Reserved	

**Table 3-6: Mating Connector Part Numbers for the 25-Pin Feedback Connector**

Mating Connector	Aerotech P/N	Third Party P/N
Backshell	ECK00656	Amphenol #17E-1726-2
Connector	ECK00300	FCI DB25S064TLF

### 3.2. Motor and Feedback Wiring

All motor and controller manufacturers have their own designations for motor phases A/B/C and Hall signals A/B/C (refer to [Section 3.5](#) for motor phasing). Shielded cables are required for the motor and feedback connections.

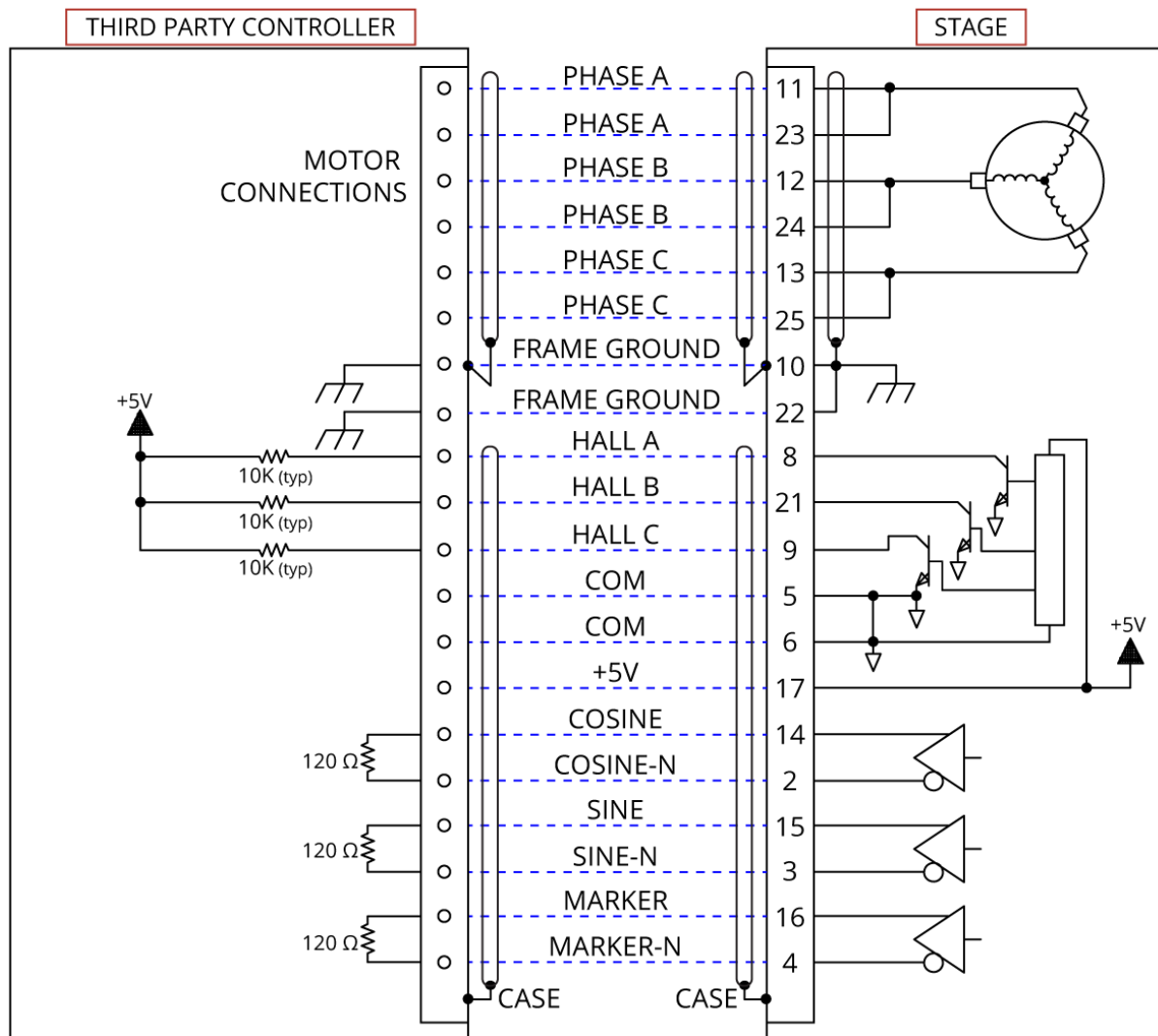
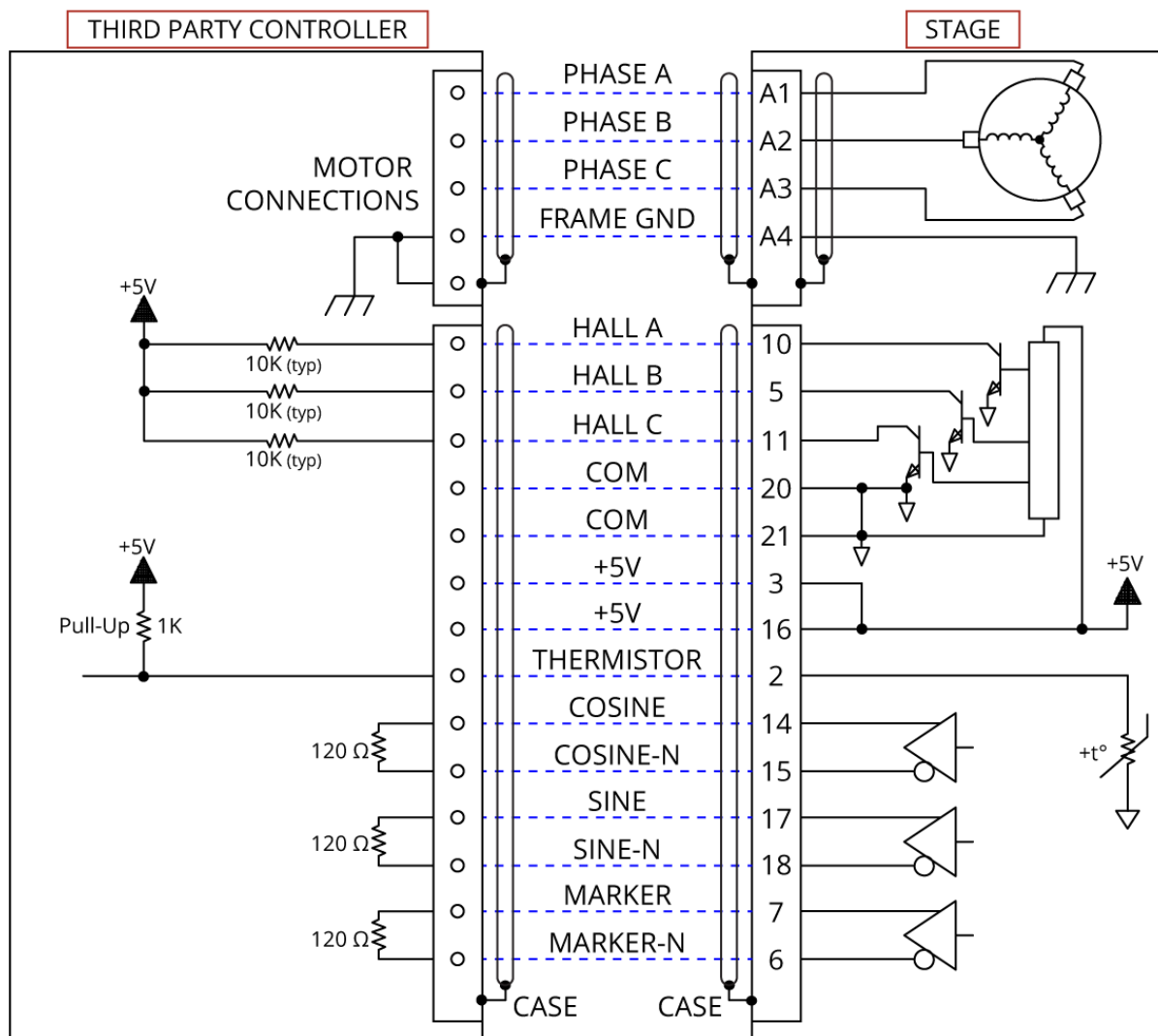


Figure 3-1: Motor and Feedback Wiring (single connector, ABRS150MP)



**Figure 3-2: Motor and Feedback Wiring (two connectors, ABRS200MP, ABRS250MP, ABRS300MP)**

### 3.3. Motor and Feedback Specifications

**Table 3-7: Feedback Specifications**

Hall-Effect Sensors Specifications	
Supply Voltage	5 V $\pm$ 5%
Supply Current	50 mA
Output Type	Open Collector
Output Voltage	24 V max (pull up)
Output Current	5 mA (sinking)

Thermistor Specifications	
Polarity	Logic "0" (no fault)
	Logic "1" (over-temperature fault)
Cold Resistance	$\sim 100 \Omega$
Hot Resistance	$\sim 10 \text{ K}$
<b>Note:</b> 1K pull-up to +5V recommended.	

Encoder Specifications	
Supply Voltage	5 V $\pm$ 5%
Supply Current	250 mA (typical)
Output Signals	<b>Sinusoidal Type (Incremental Encoder):</b> 1 V <sub>pk-pk</sub> into 120 $\Omega$ Load (differential signals SIN+, SIN-, COS+, COS- are .5 V <sub>pk-pk</sub> relative to ground.)
	<b>Digital Output (Incremental Encoder):</b> RS422/485 compatible

**Table 3-8: Encoder Resolution Specifications**

	ABRS150MP	ABRS200MP	ABRS250MP	ABRS300MP
Fundamental Resolution	3600 lines/rev	8192 lines/rev	11,840 lines/rev	18,000 lines/rev
-E1 (Sine)	360 arc sec/line	158 arc sec/line	109 arc sec/line	72 arc sec/line
-E2 (Square wave x50)	1.8 arc sec/line	0.79 arc sec/line	0.547 arc sec/line	0.36 arc sec/line
<b>NOTE:</b> Fundamental resolution of sine wave output from encoder.				

**Table 3-9: Maximum Speed (rpm) Per Encoder Option**

	ABRS150MP	ABRS200MP	ABRS250MP	ABRS300MP
-E1	300 rpm	300 rpm	500 rpm	500 rpm
-E2	300 rpm	234 rpm	162 rpm	107 rpm

**NOTE:** The encoders used on all ABRS series stages come standard with a 16 MHz clock rate. Aerotech can provide slower or faster clock rates to match the controller being used. Consult Aerotech for more information.

**Table 3-10: ABRS150MP Motor Specifications (S-50-39-A)**

		S-50-39
<b>Performance Specifications (1,5)</b>		
Winding Designation		-A
Stall Torque, Cont. (2)	N·m	0.20
Peak Torque (3)	N·m	0.82
<b>Electrical Specifications (5)</b>		
Winding Designation		-A
BEMF Const., line-line, Max	$V_{pk}/krpm$	10.3
Continuous Current, Stall (2)	$A_{pk}$	2.4
	$A_{rms}$	1.7
Peak Current, Stall (2)	$A_{pk}$	9.6
Torque Constant (4, 9)	$N·m/A_{pk}$	0.09
	$N·m/A_{rms}$	0.12
Motor Constant (2, 4)	$N·m/\sqrt{W}$	0.034
Resistance, 25°C, line-line	$\Omega$	6.6
Inductance, line-line	mH	1.50
Maximum Bus Voltage	$V_{DC}$	80
Thermal Resistance	°C/W	2.02
Number of Poles	--	8
1. Performance is dependent upon heat sink configuration, system cooling conditions, and ambient temperature 2. Values shown @ 75°C rise above a 25 °C ambient temperature, with housed motor mounted to a 250 mm x 250 mm x 6 mm aluminum heat sink 3. Peak force assumes correct rms current; consult Aerotech. 4. Torque constant and motor constant specified at stall 5. All performance and electrical specifications $\pm 10\%$ 6. Specifications given are for the motor only. When integrated into a housing with bearings additional losses should be considered. 7. Maximum winding temperature is 100 °C (thermistor trips at 100 °C) 8. Ambient operating temperature range 0 °C - 25 °C; consult Aerotech for performance in elevated ambient temperatures 9. All Aerotech amplifiers are rated $A_{pk}$ ; use torque constant in $N·m/A_{pk}$ when sizing		

**Table 3-11: ABRS200MP Motor Specifications (S-76-35-A)**

		S-76-35
<b>Performance Specifications (1,5)</b>		
Winding Designation		-A
Stall Torque, Cont. (2)	N·m	0.48
Peak Torque (3)	N·m	1.92
<b>Electrical Specifications (5)</b>		
Winding Designation		-A
BEMF Const., line-line, Max	$V_{pk}/krpm$	29.1
Continuous Current, Stall (2)	$A_{pk}$	2.0
	$A_{rms}$	1.4
Peak Current, Stall (2)	$A_{pk}$	8.0
	$A_{rms}$	5.7
Torque Constant (4, 9)	$N \cdot m/A_{pk}$	0.24
	$N \cdot m/A_{rms}$	0.34
Motor Constant (2, 4)	$N \cdot m/\sqrt{W}$	0.075
Resistance, 25°C, line-line	$\Omega$	10.5
Inductance, line-line	mH	1.40
Maximum Bus Voltage	$V_{DC}$	80
Thermal Resistance	°C/W	1.83
Number of Poles	--	14
1. Performance is dependent upon heat sink configuration, system cooling conditions, and ambient temperature 2. Values shown @ 75°C rise above a 25 °C ambient temperature, with housed motor mounted to a 250 mm x 250 mm x 6 mm aluminum heat sink 3. Peak force assumes correct rms current; consult Aerotech. 4. Torque constant and motor constant specified at stall 5. All performance and electrical specifications $\pm 10\%$ 6. Specifications given are for the motor only. When integrated into a housing with bearings additional losses should be considered. 7. Maximum winding temperature is 100 °C (thermistor trips at 100 °C) 8. Ambient operating temperature range 0 °C - 25 °C; consult Aerotech for performance in elevated ambient temperatures 9. All Aerotech amplifiers are rated $A_{pk}$ ; use torque constant in $N \cdot m/A_{pk}$ when sizing		

**Table 3-12: ABRS250MP Motor Specifications (S-130-39-A)**

		S-130-39
<b>Performance Specifications (1,5)</b>		
Winding Designation		-A
Stall Torque, Cont. (2)	N·m	2.36
Peak Torque (3)	N·m	9.42
<b>Electrical Specifications (5)</b>		
Winding Designation		-A
BEMF Const., line-line, Max	$V_{pk}/krpm$	75.1
Continuous Current, Stall (2)	$A_{pk}$	3.8
	$A_{rms}$	2.7
Peak Current, Stall (2)	$A_{pk}$	15.2
	$A_{rms}$	10.7
Torque Constant (4, 9)	$N \cdot m/A_{pk}$	0.62
	$N \cdot m/A_{rms}$	0.88
Motor Constant (2, 4)	$N \cdot m/\sqrt{W}$	0.265
Resistance, 25°C, line-line	$\Omega$	5.6
Inductance, line-line	mH	1.70
Maximum Bus Voltage	$V_{DC}$	80
Thermal Resistance	°C/W	0.95
Number of Poles	--	18
1. Performance is dependent upon heat sink configuration, system cooling conditions, and ambient temperature 2. Values shown @ 75°C rise above a 25 °C ambient temperature, with housed motor mounted to a 330 mm x 330 mm x 13 mm aluminum heat sink 3. Peak force assumes correct rms current; consult Aerotech. 4. Torque constant and motor constant specified at stall 5. All performance and electrical specifications $\pm 10\%$ 6. Specifications given are for the motor only. When integrated into a housing with bearings additional losses should be considered. 7. Maximum winding temperature is 100 °C (thermistor trips at 100 °C) 8. Ambient operating temperature range 0 °C - 25 °C; consult Aerotech for performance in elevated ambient temperatures 9. All Aerotech amplifiers are rated $A_{pk}$ ; use torque constant in $N \cdot m/A_{pk}$ when sizing		

**Table 3-13: ABRS300MP Motor Specifications (S-180-44-A)**

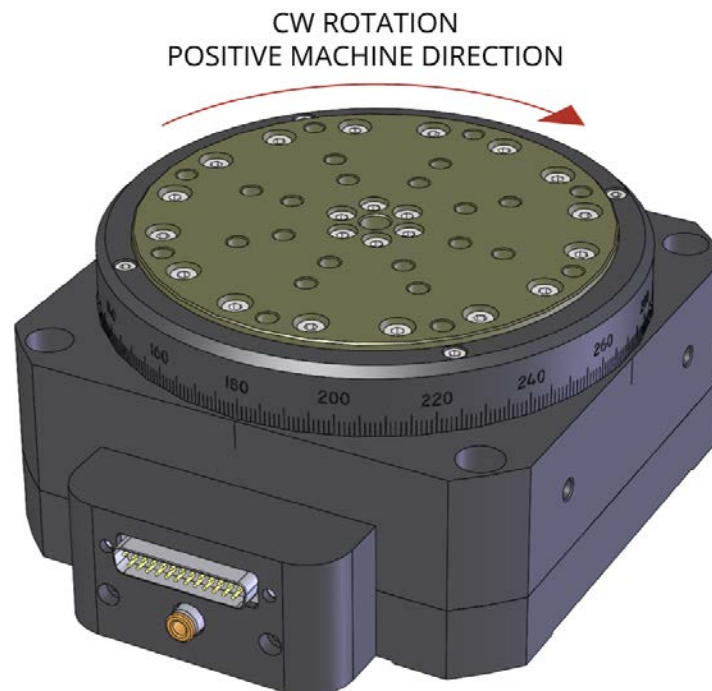
		S-180-44
<b>Performance Specifications (1,5)</b>		
Winding Designation		-A
Stall Torque, Cont. (2)	N·m	5.99
Peak Torque (3)	N·m	23.98
<b>Electrical Specifications (5)</b>		
Winding Designation		-A
BEMF Const., line-line, Max	$V_{pk}/krpm$	268.7
Continuous Current, Stall (2)	$A_{pk}$	2.7
	$A_{rms}$	1.9
Peak Current, Stall (2)	$A_{pk}$	10.8
	$A_{rms}$	7.6
Torque Constant (4, 9)	$N·m/A_{pk}$	2.22
	$N·m/A_{rms}$	3.14
Motor Constant (2, 4)	$N·m/\sqrt{W}$	0.628
Resistance, 25°C, line-line	$\Omega$	12.8
Inductance, line-line	mH	3.40
Maximum Bus Voltage	$V_{DC}$	80
Thermal Resistance	°C/W	0.82
Number of Poles	--	18
1. Performance is dependent upon heat sink configuration, system cooling conditions, and ambient temperature 2. Values shown @ 75°C rise above a 25 °C ambient temperature, with housed motor mounted to a 330 mm x 330 mm x 13 mm aluminum heat sink 3. Peak force assumes correct rms current; consult Aerotech. 4. Torque constant and motor constant specified at stall 5. All performance and electrical specifications $\pm 10\%$ 6. Specifications given are for the motor only. When integrated into a housing with bearings additional losses should be considered. 7. Maximum winding temperature is 100 °C (thermistor trips at 100 °C) 8. Ambient operating temperature range 0 °C - 25 °C; consult Aerotech for performance in elevated ambient temperatures 9. All Aerotech amplifiers are rated $A_{pk}$ ; use torque constant in $N·m/A_{pk}$ when sizing		



### 3.4. Limits, Marker, and Machine Direction

Aerotech stages are configured to have positive and negative "machine" directions. The machine direction defines the phasing of the feedback and motor signals and is dictated by the stage wiring (refer to [Section 3.5](#) for Motor and Feedback phasing information). Programming direction of a stage is set by the controller that is used to move the stage. Programming direction is typically selectable in the controller, while machine direction is hardwired in the stage. [Figure 3-3](#) shows the machine direction of ABRS stages.

Standard ABRS stages do not include end-of-travel limits. Consult the factory for a custom solution.



**Figure 3-3: Machine Direction**

### 3.5. Motor and Feedback Phasing

Motor phase voltage is measured relative to the virtual wye common point.

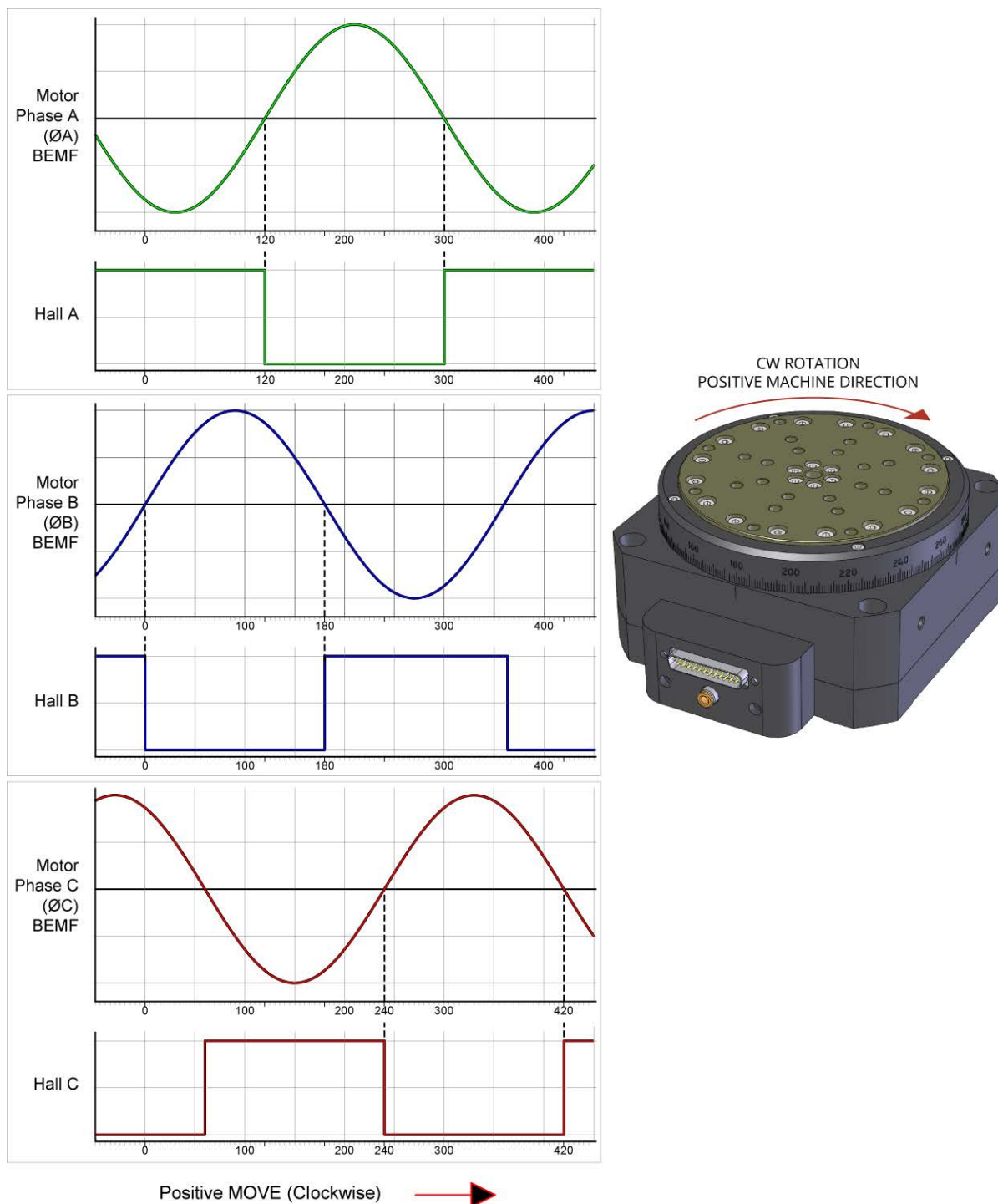
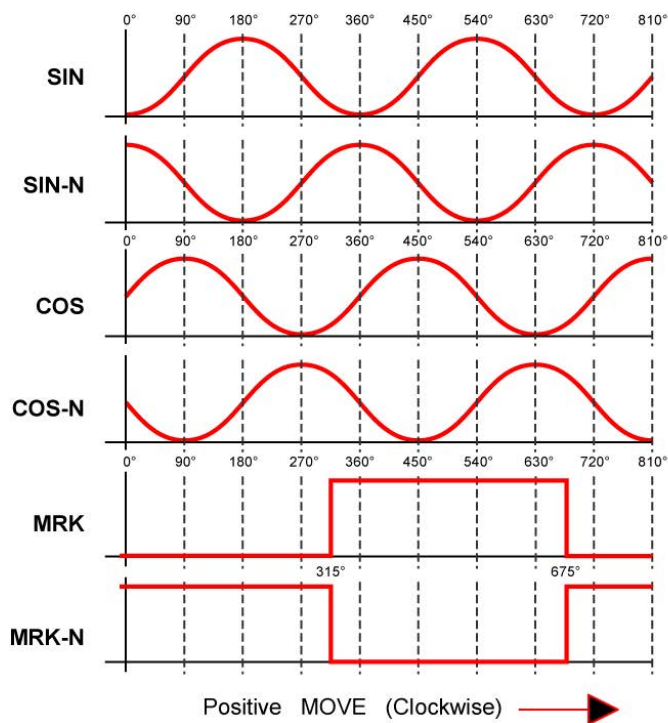
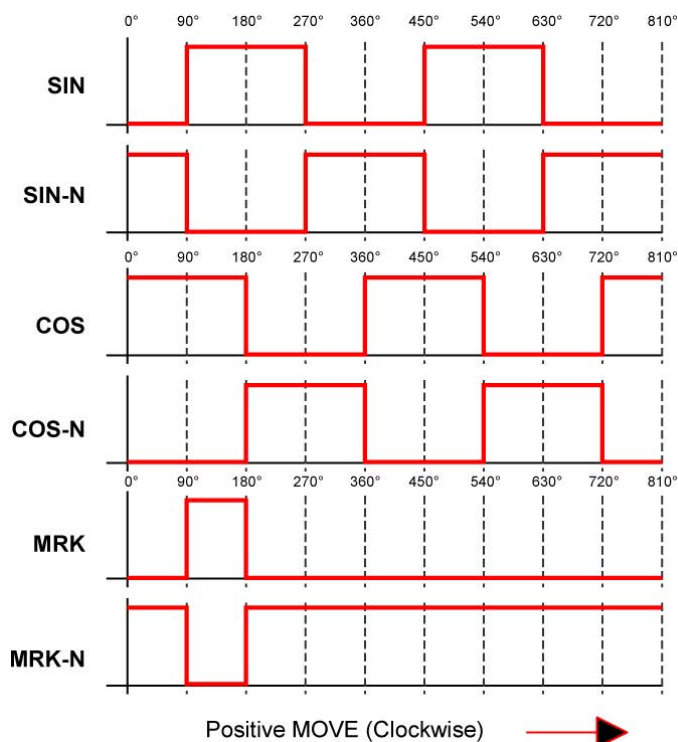


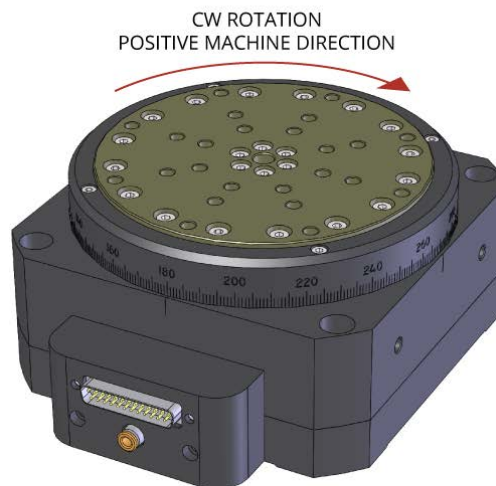
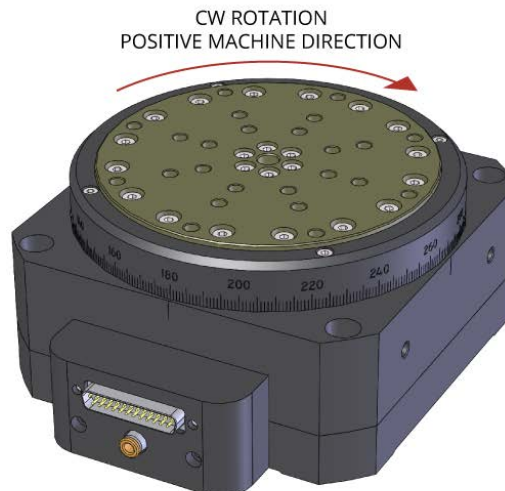
Figure 3-4: Hall Phasing



**Figure 3-5: Analog Encoder Phasing Reference Diagram (-E1 Encoder Option)**



**Figure 3-6: Digital Encoder Phasing Reference Diagram (-E2 Encoder Option)**



*This page intentionally left blank.*

## Chapter 4: Maintenance

The ABRS series stages are designed to require minimum maintenance. Due to the non-contact air bearing design, there are no friction surfaces or dynamic seals to wear or require lubrication. This chapter will detail the cleaning process and specify recommended cleaning solvents.



**DANGER:** To minimize the possibility of bodily injury or death, disconnect all electrical power prior to performing any maintenance or making adjustments to the equipment.

**NOTE:** The stage must be kept free of foreign matter and moisture; otherwise, the performance and life expectancy of the stage will be reduced.

### 4.1. Service and Inspection Schedule

Inspect the ABRS at least once per month. A longer or shorter inspection interval may be required depending on the application and conditions, such as the duty cycle, speed, and environment.

Monthly inspections should include but not be limited to:

- Visually inspect the stage and cables.
- Re-tighten loose connectors.
- Replace or repair damaged cables.
- Clean the ABRS and any components and cables as needed.
- Repair any damage before operating the ABRS.
- Inspect and perform an operational check on all safeguards and protective devices.

In general, repair and/or replacement of damaged or malfunctioning components by Aerotech field service personnel is not possible. Repair typically requires that the unit be returned to the factory. Please contact Aerotech Global Technical Support for more information.

## 4.2. Cleaning and Lubrication



**DANGER:** To minimize the possibility of bodily injury or death, disconnect all electrical power prior to performing any maintenance or making adjustments to the equipment.

### Cleaning

Before using a cleaning solvent on any part of the ABRS, blow away small particles and dust with nitrogen or, less preferably, clean, dry, compressed air.

Any external metal surface of the ABRS can be cleaned with isopropyl alcohol on a lint-free cloth. Avoid getting excess cleaning solvent on the surfaces, as it could damage the delicate electronics inside.



**WARNING:** Make sure that all solvent has completely evaporated before attempting to move the stage.

### Lubrication

There are no elements on ABRS stages that require lubrication.

### 4.3. Troubleshooting

Symptom	Possible Cause and Solution
Stage will not move	Brake not released (if equipped with brake; refer to stage documentation). Controller trap or fault (refer to the Controller documentation).
Stage moves uncontrollably	Encoder (sine and cosine) signal connections (refer to <a href="#">Chapter 3</a> and Controller documentation). Motor Connections (refer to <a href="#">Chapter 3</a> and the Controller documentation).
Stage oscillates or squeals	Gains misadjusted (refer to the Controller documentation). Encoder signals (refer to the Controller documentation).

*This page intentionally left blank.*



## Appendix A: Warranty and Field Service

Aerotech, Inc. warrants its products to be free from harmful defects caused by faulty materials or poor workmanship for a minimum period of one year from date of shipment from Aerotech. Aerotech's liability is limited to replacing, repairing or issuing credit, at its option, for any products that are returned by the original purchaser during the warranty period. Aerotech makes no warranty that its products are fit for the use or purpose to which they may be put by the buyer, whether or not such use or purpose has been disclosed to Aerotech in specifications or drawings previously or subsequently provided, or whether or not Aerotech's products are specifically designed and/or manufactured for buyer's use or purpose. Aerotech's liability on any claim for loss or damage arising out of the sale, resale, or use of any of its products shall in no event exceed the selling price of the unit.

THE EXPRESS WARRANTY SET FORTH HEREIN IS IN LIEU OF AND EXCLUDES ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, BY OPERATION OF LAW OR OTHERWISE. IN NO EVENT SHALL AEROTECH BE LIABLE FOR CONSEQUENTIAL OR SPECIAL DAMAGES.

### Return Products Procedure

Claims for shipment damage (evident or concealed) must be filed with the carrier by the buyer. Aerotech must be notified within thirty (30) days of shipment of incorrect material. No product may be returned, whether in warranty or out of warranty, without first obtaining approval from Aerotech. No credit will be given nor repairs made for products returned without such approval. A "Return Materials Authorization (RMA)" number must accompany any returned product(s). The RMA number may be obtained by calling an Aerotech service center or by submitting the appropriate request available on our website ([www.aerotech.com](http://www.aerotech.com)). Products must be returned, prepaid, to an Aerotech service center (no C.O.D. or Collect Freight accepted). The status of any product returned later than thirty (30) days after the issuance of a return authorization number will be subject to review.

Visit <https://www.aerotech.com/global-technical-support.aspx> for the location of your nearest Aerotech Service center.

### Returned Product Warranty Determination

After Aerotech's examination, warranty or out-of-warranty status will be determined. If upon Aerotech's examination a warranted defect exists, then the product(s) will be repaired at no charge and shipped, prepaid, back to the buyer. If the buyer desires an expedited method of return, the product(s) will be shipped collect. Warranty repairs do not extend the original warranty period.

**Fixed Fee Repairs** - Products having fixed-fee pricing will require a valid purchase order or credit card particulars before any service work can begin.

**All Other Repairs** - After Aerotech's evaluation, the buyer shall be notified of the repair cost. At such time the buyer must issue a valid purchase order to cover the cost of the repair and freight, or authorize the product(s) to be shipped back as is, at the buyer's expense. Failure to obtain a purchase order number or approval within thirty (30) days of notification will result in the product(s) being returned as is, at the buyer's expense.

Repair work is warranted for ninety (90) days from date of shipment. Replacement components are warranted for one year from date of shipment.

### Rush Service

At times, the buyer may desire to expedite a repair. Regardless of warranty or out-of-warranty status, the buyer must issue a valid purchase order to cover the added rush service cost. Rush service is subject to Aerotech's approval.

### On-site Warranty Repair

If an Aerotech product cannot be made functional by telephone assistance or by sending and having the customer install replacement parts, and cannot be returned to the Aerotech service center for repair, and if Aerotech determines the problem could be warranty-related, then the following policy applies:

Aerotech will provide an on-site Field Service Representative in a reasonable amount of time, provided that the customer issues a valid purchase order to Aerotech covering all transportation and subsistence costs. For warranty field repairs, the customer will not be charged for the cost of labor and material. If service is rendered at times other than normal work periods, then special rates apply.

If during the on-site repair it is determined the problem is not warranty related, then the terms and conditions stated in the following "On-Site Non-Warranty Repair" section apply.

### On-site Non-Warranty Repair

If any Aerotech product cannot be made functional by telephone assistance or purchased replacement parts, and cannot be returned to the Aerotech service center for repair, then the following field service policy applies:

Aerotech will provide an on-site Field Service Representative in a reasonable amount of time, provided that the customer issues a valid purchase order to Aerotech covering all transportation and subsistence costs and the prevailing labor cost, including travel time, necessary to complete the repair.

### Service Locations

<http://www.aerotech.com/contact-sales.aspx?mapState=showMap>

USA, CANADA, MEXICO	CHINA	GERMANY
Aerotech, Inc. Global Headquarters Phone: +1-412-967-6440 Fax: +1-412-967-6870	Aerotech China Full-Service Subsidiary Phone: +86 (21) 5508 6731	Aerotech Germany Full-Service Subsidiary Phone: +49 (0)911 967 9370 Fax: +49 (0)911 967 93720
TAIWAN	UNITED KINGDOM	
Aerotech Taiwan Full-Service Subsidiary Phone: +886 (0)2 8751 6690	Aerotech United Kingdom Full-Service Subsidiary Phone: +44 (0)1256 855055 Fax: +44 (0)1256 855649	

Have your customer order number ready before calling.

## Appendix B: Revision History

Revision	General Information
1.08.00	Updated: <ul style="list-style-type: none"> <li>• <a href="#">EU Declaration of Incorporation</a></li> <li>• <a href="#">Section 1.4. Air Requirements</a></li> <li>• <a href="#">Section 2.1. Unpacking and Handling the Stage</a></li> </ul>
1.07.00	Updated bus voltage from 80 to 340 VDC for ABRS200MP, ABRS250MP, and ABRS300MP ( <a href="#">Section 1.3.</a> )
1.06.00	<ul style="list-style-type: none"> <li>• Product update</li> <li>• General revision</li> <li>• Updated safety information and warnings</li> </ul>
1.05.00	Revision changes have been archived. If you need a copy of this revision, contact Aerotech Global Technical Support.
1.04.00	
1.03.00	
1.02.00	
1.01.00	
1.00.00	

*This page intentionally left blank.*

# Index

	<b>2</b>		<b>G</b>	
		Global Technical Support		2
2006/42/EC	7		<b>H</b>	
	<b>A</b>	Hall-Effect Sensors Specifications		28
air hose	12	hose, air		12
air pressure	12	Humidity		10
air requirements	12		<b>I</b>	
airflow rate	12	Inspection Schedule		37
Altitude	10	isopropyl alcohol		38
Ambient Temperature	10		<b>L</b>	
	<b>C</b>	label		13
cleaning		lubrication		38
mounting surface	18	Lubrication		38
solvents	38		<b>M</b>	
Cleaning	38	MCA03094		12
compressed air	12	mounting surface		
	<b>D</b>	cleaning		18
Dimensions	14	securing stage		18
Directive 2006/42/EC	7		<b>N</b>	
drop in pressure	12	nitrogen		12
	<b>E</b>		<b>P</b>	
Electrical Installation	21	part number		13
Electrical Specifications		Performance Specifications		
S-130	31	S-130		31
S-180	32	S-180		32
S-50	29	S-50		29
S-76	30	S-76		30
EN 60204-1 2010	7	pressure switch		12
EN ISO 12100 2010	7	Protection Rating		10
Encoder Specifications	28	protective ground connection		22
	<b>F</b>		<b>R</b>	
field service	37	rate, airflow		12

**S**

S-130	
Electrical Specifications	31
Performance Specifications	31
S-180	
Electrical Specifications	32
Performance Specifications	32
S-50	
Electrical Specifications	29
S-50 Performance Specifications	29
S-76	
Electrical Specifications	30
Performance Specifications	30
Securing the Stage to the Mounting Surface	18
serial number	13
solvents	38
Specifications	11
stabilizing stage	13
stage	
distortion	18
stabilizing	13
Support	2

**T**

Technical Support	2
Thermistor Specifications	28

**V**

Vibration	10
-----------	----

**W**

Warranty and Field Service	41
----------------------------	----